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Experimental and Computational Investigations of a High-Power, Long-Pulse Relativistic Klystron Oscillator (Postprint)

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14. ABSTRACT
A high-power, long-pulse source of high-power microwaves has been investigated experimentally and through a variety of modeling and simulation efforts at the Air Force Research Laboratory. The relativistic klystron oscillator (RKO) is an injection-locked oscillator capable of producing 200ns duration pulses exceeding 1 GW output power at 1270-1275 MHz. Extensive experiments have been closely coupled with computational modeling and simulation to explore a wide range of issues encountered in the operation and diagnostics of the device. The experiment uses coupled ¾λ cavities to modulate the electron beam. Calculations using both HFSS and ICEPIC have been used to reproduce cold test frequency characteristics of the isolated and of the coupled cavities, including the finite conductivity of the RKO walls. Calculations using reduced physics models and ICEPIC have been used to explore the coupling between the beam and the cavities. A highlight of the modeling efforts is a series of calculations, which for the first time predict cavity saturation voltages at sub-virtual-cathode levels. Previous calculations were either restricted to ¼λcavities, or showed saturation voltages at the virtual cathode levels. Comparisons between experiment and computation will be presented.

15. SUBJECT TERMS
Microwave, HPM, Experiment, Simulation, RKO

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EXPERIMENTAL AND COMPUTATIONAL INVESTIGATIONS OF A HIGH-POWER, LONG-PULSE RELATIVISTIC KLYSTRON OSCILLATOR
30 OCTOBER 2006

Dr. Kyle Hendricks(AFRL)

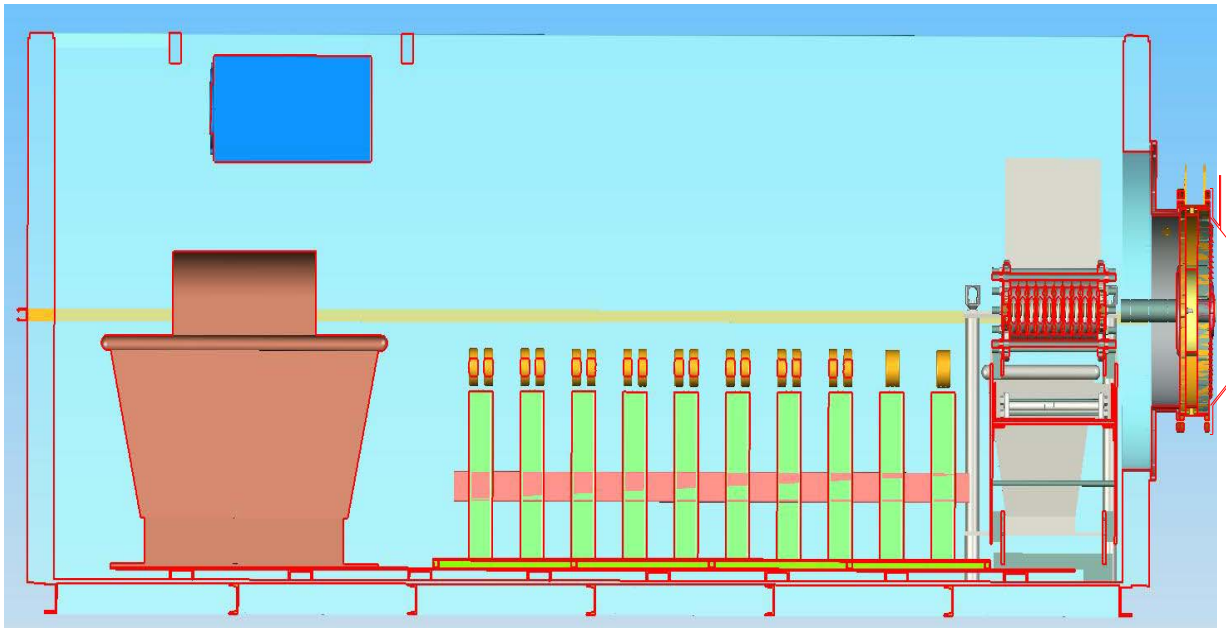
Dr. Jack Watrous(NumerEx)

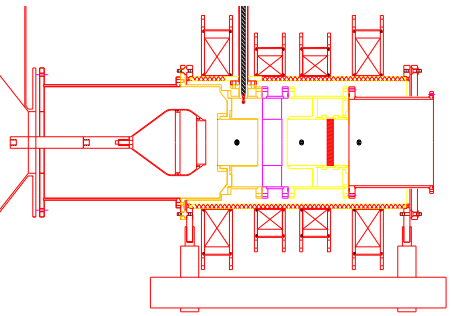
Dr. John Luginsland(NumerEx)

Abstract

A high-power, long-pulse source of high-power microwaves has been investigated experimentally and through a variety of modeling and simulation efforts at the Air Force Research Laboratory. The relativistic klystron oscillator (RKO) is an injection-locked oscillator capable of producing 200ns duration pulses exceeding 1 GW output power at 1270-1275 MHz. Extensive experiments have been closely coupled with computational modeling and simulation to explore a wide range of issues encountered in the operation and diagnostics of the device. The experiment uses coupled ¾λ cavities to modulate the electron beam. Calculations using both HFSS and ICEPIC have been used to reproduce cold test frequency characteristics of the isolated and of the coupled cavities, including the finite conductivity of the RKO walls. Calculations using reduced physics models and ICEPIC have been used to explore the coupling between the beam and the cavities. A highlight of the modeling efforts is a series of calculations, which for the first time predict cavity saturation voltages at sub-virtual-cathode levels. Previous calculations were either restricted to ¼λcavities, or showed saturation voltages at the virtual cathode levels. Comparisons between experiment and computation will be presented.

Pulser-RKO Geometry





RKO Magnetized Diode & Coupled Cavities

ETDL Pulser:

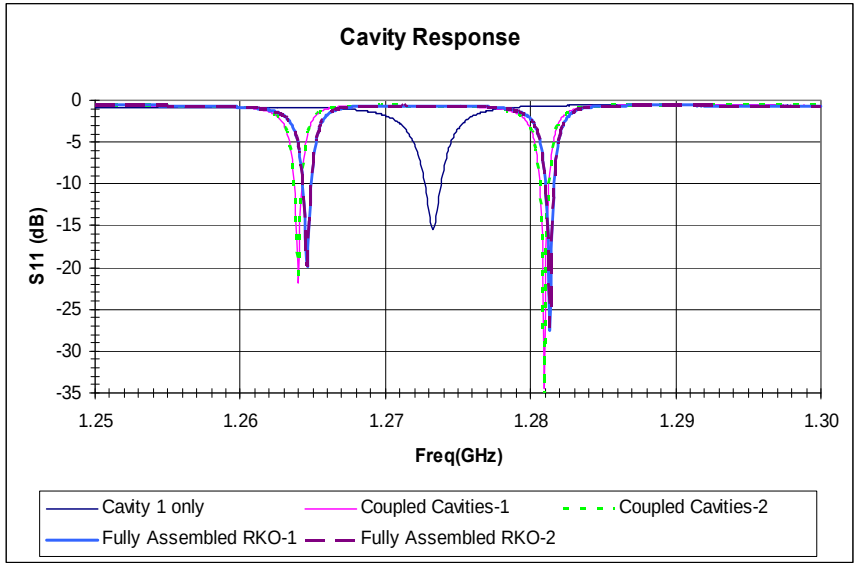
550 kV

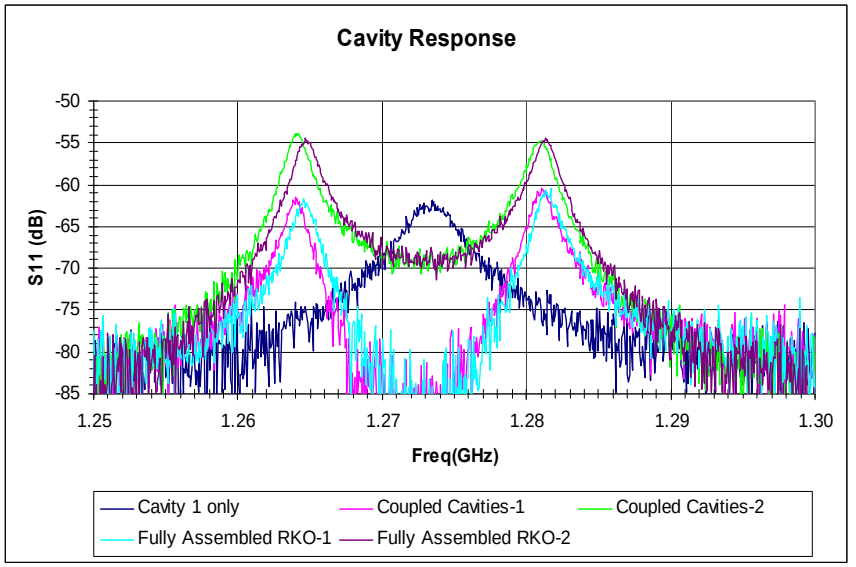
20 Ω

560 nsec (FWHM)

Radial Ballast Resistor

Cold Test Results



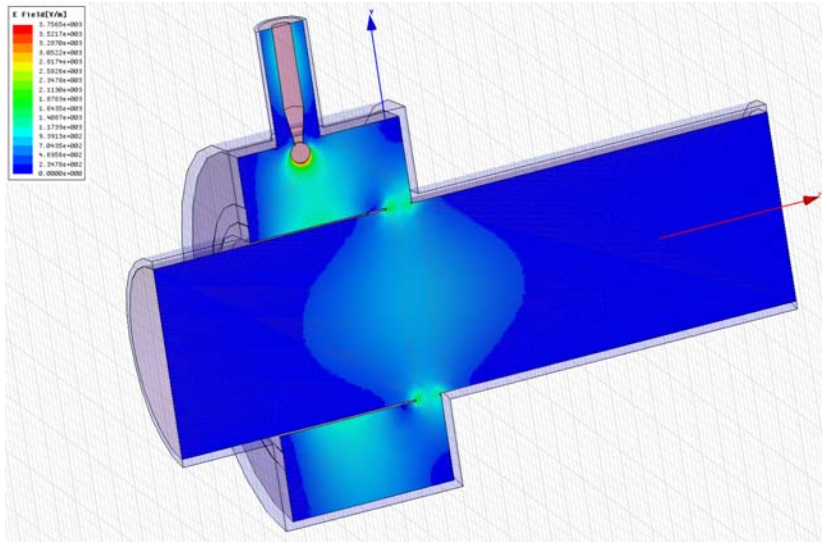


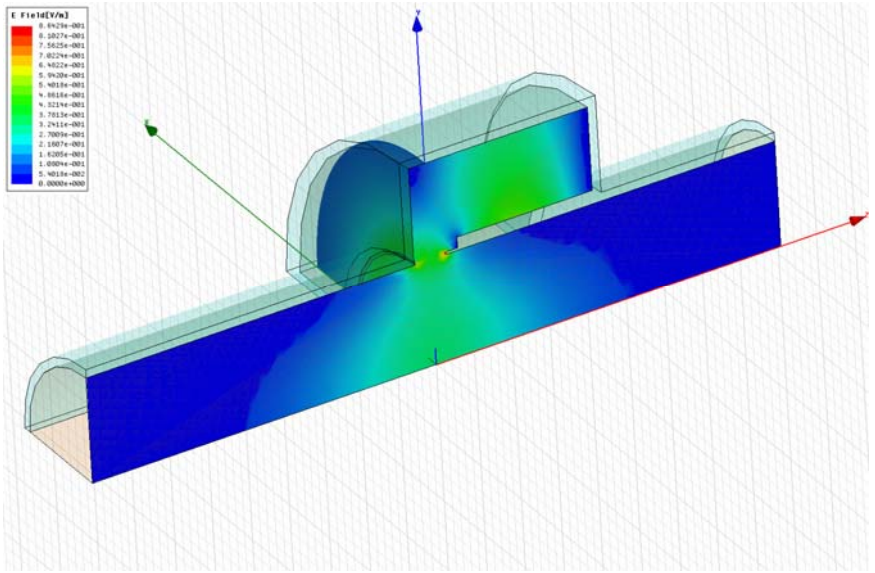
Coupled Cavity Modes

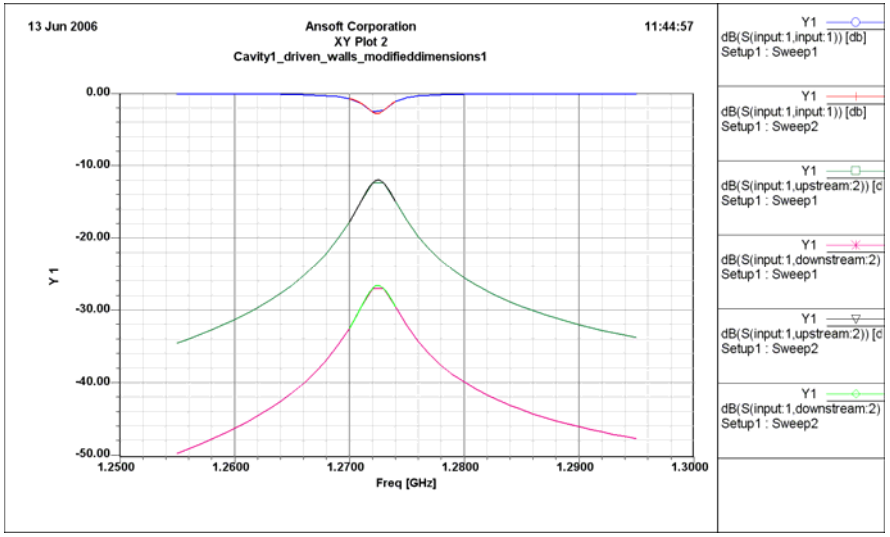
0-mode= 1.264 GHz

π-mode= 1.281 GHz

HFSS Single Cavity Simulations



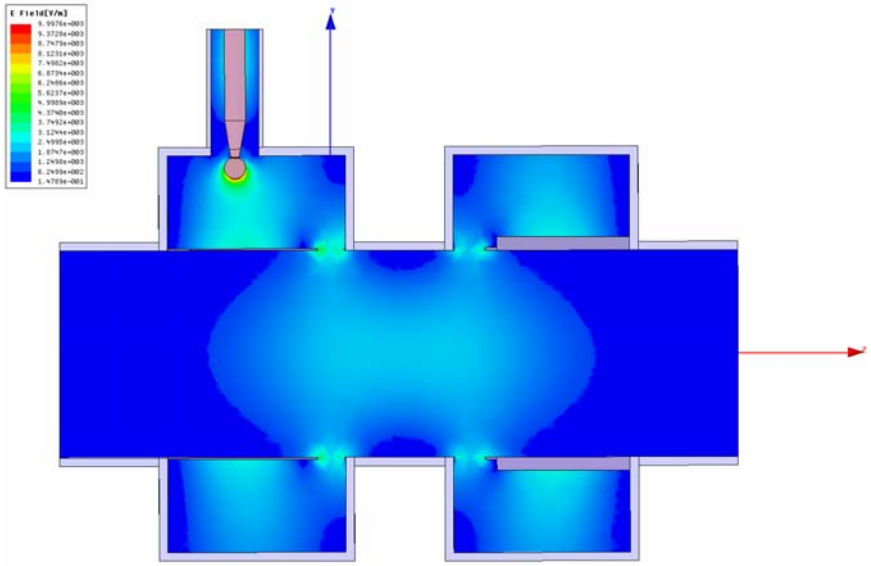


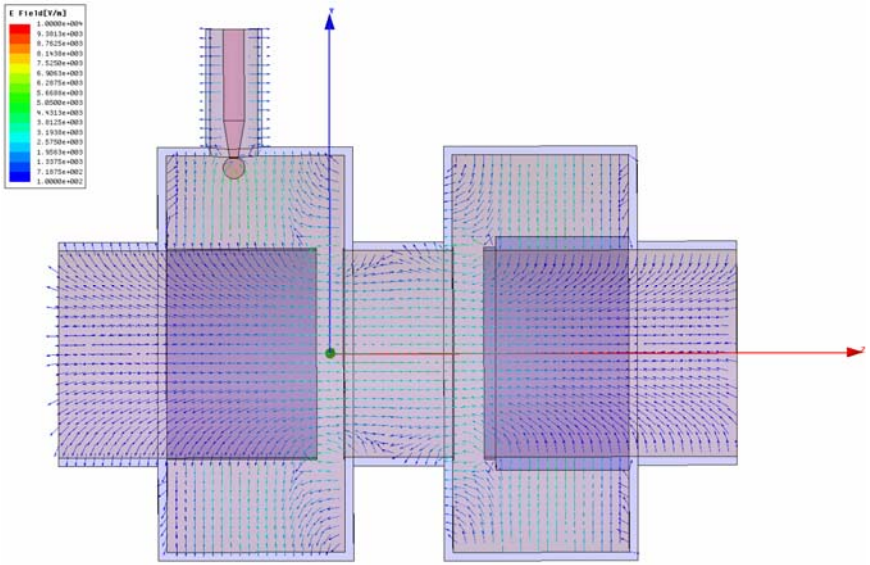


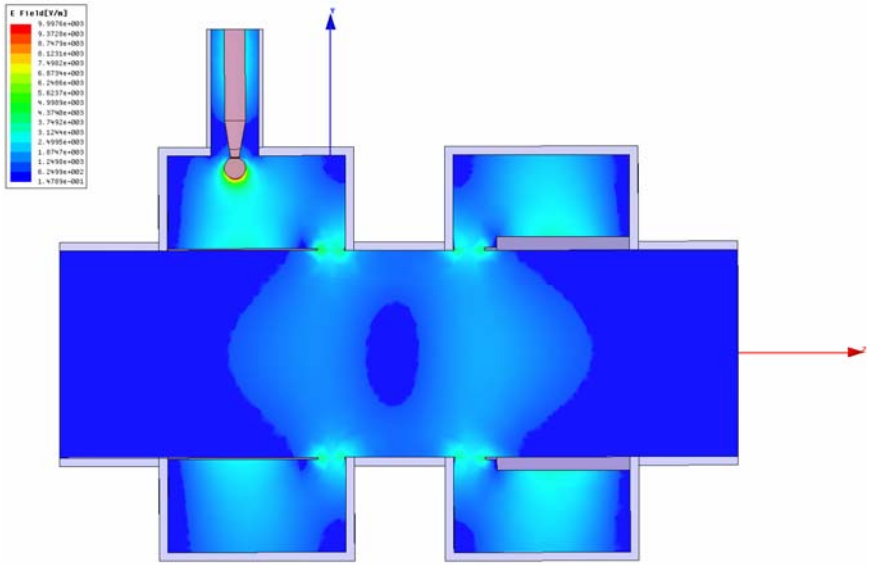
2nd Cavity Eigenmode	freq	Q
λ/4	0.4218 GHZ	2002
3λ/4	1.274 GHz	3061

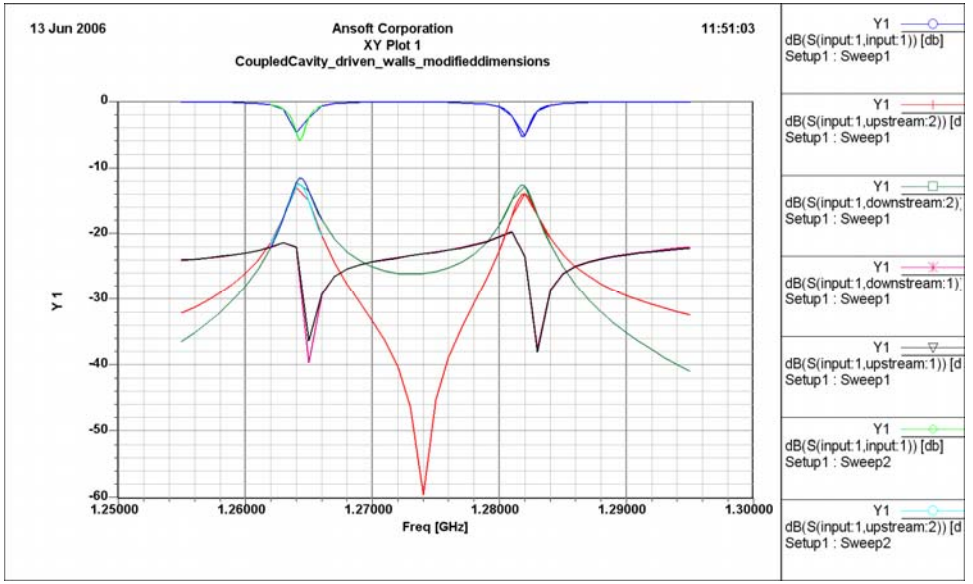
Using σ for 304L stainless steel

HFSS Coupled Cavity Simulation

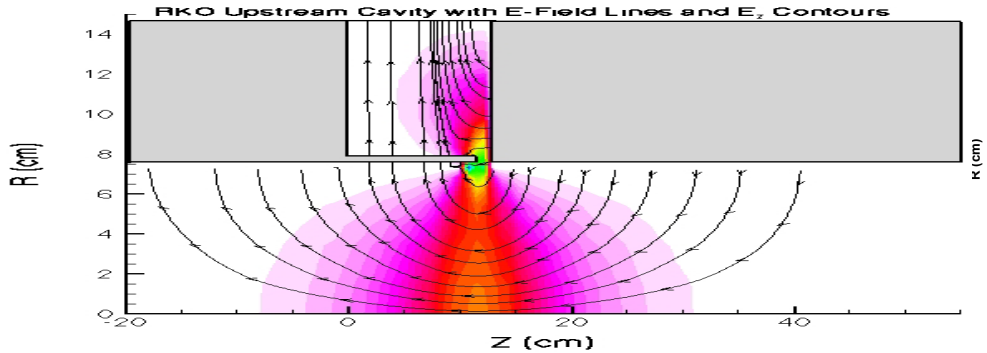


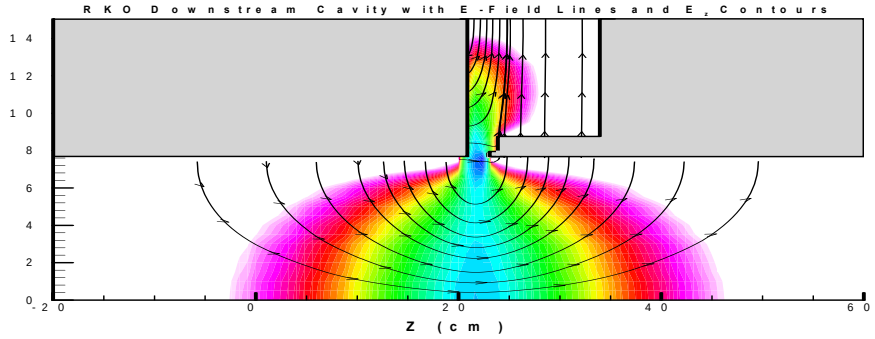


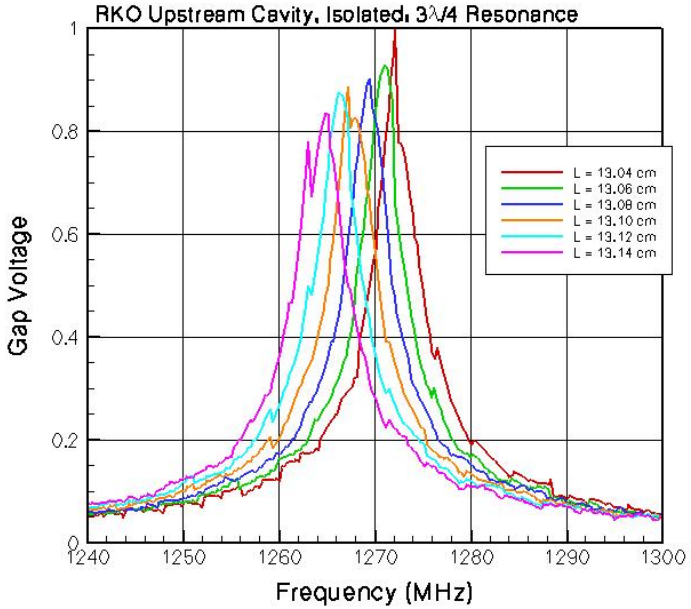


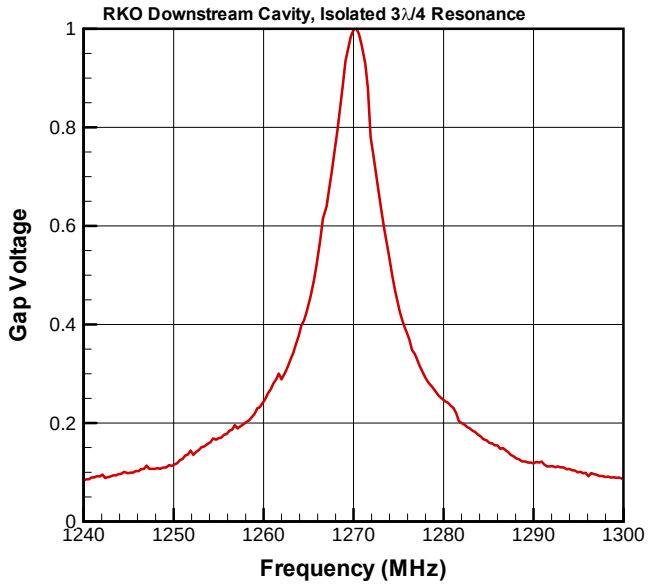


ICEPIC Single Cavity

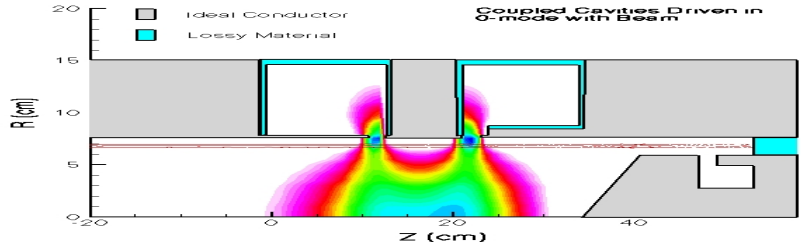


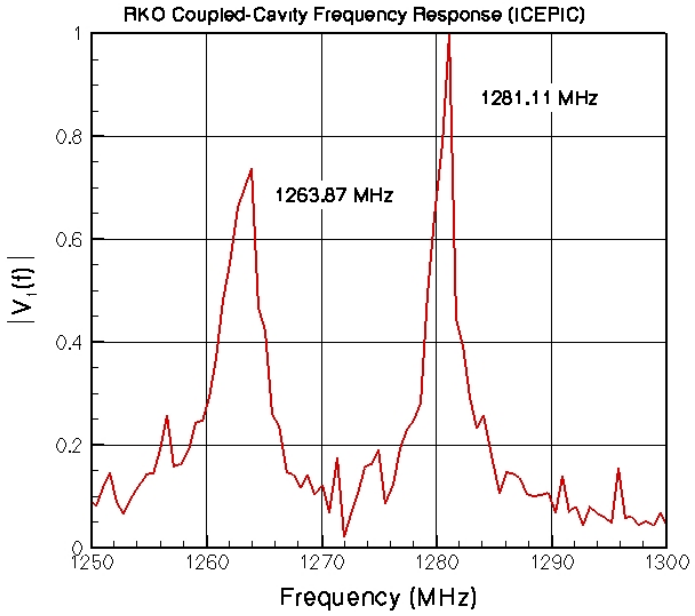


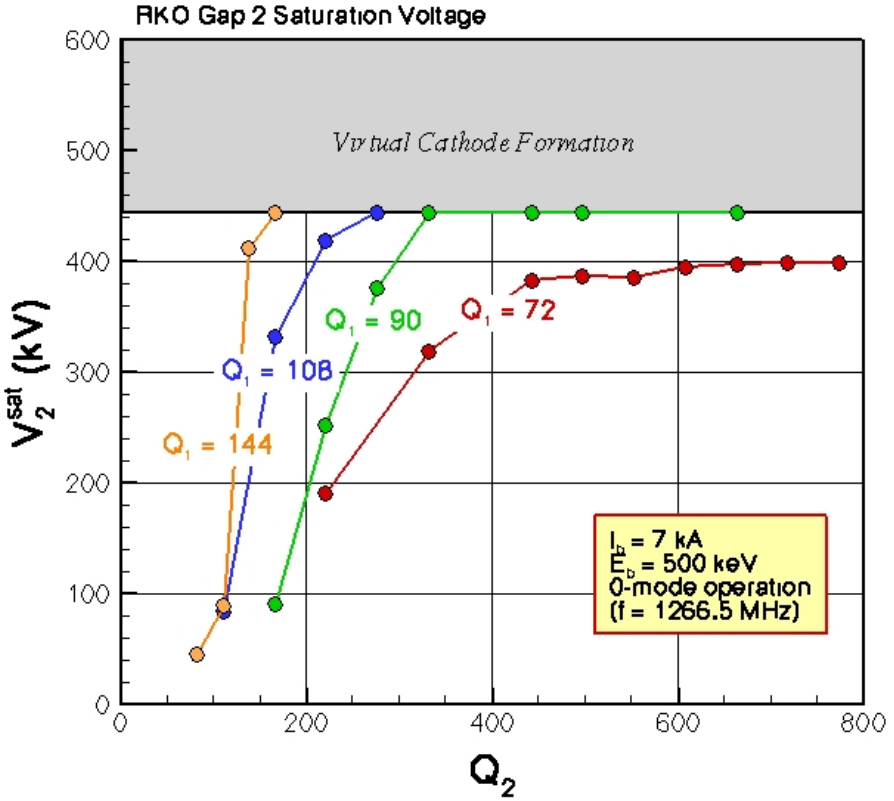




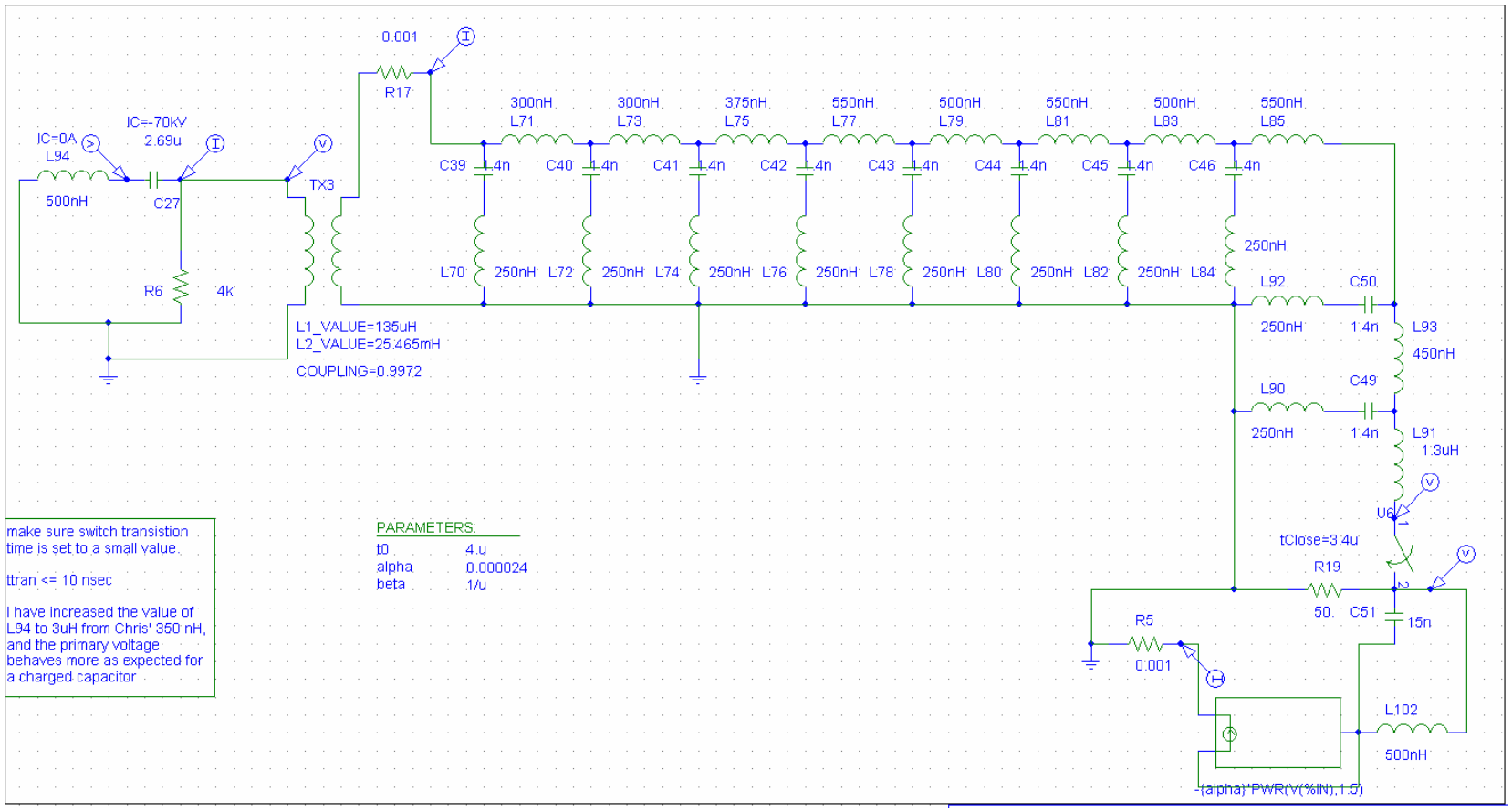
ICEPIC Coupled Cavity





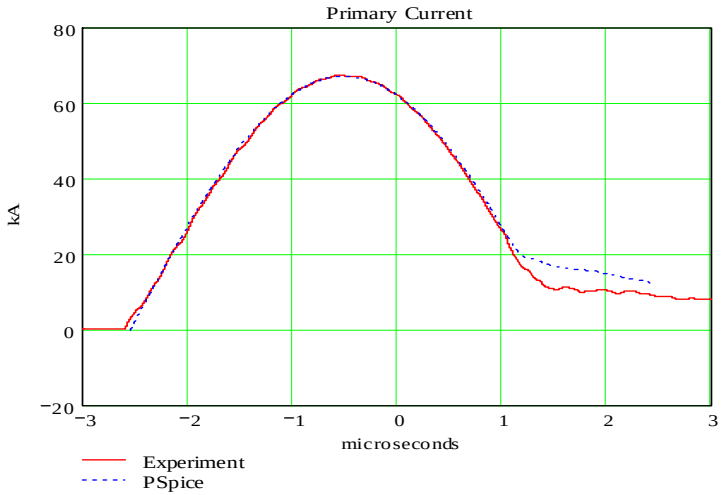


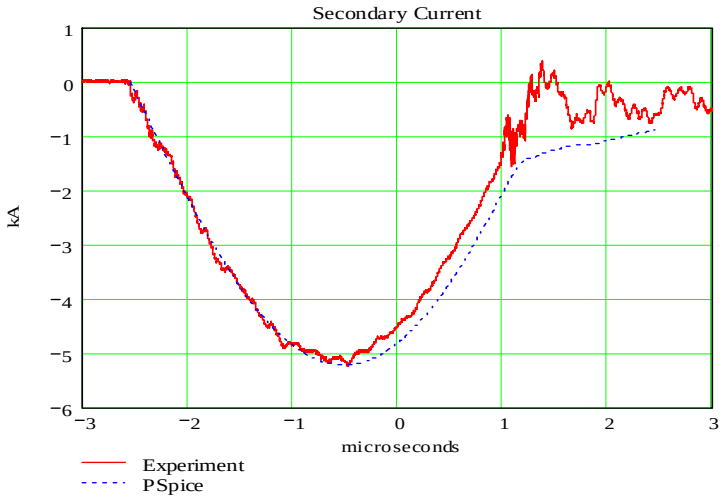
Pspice Models

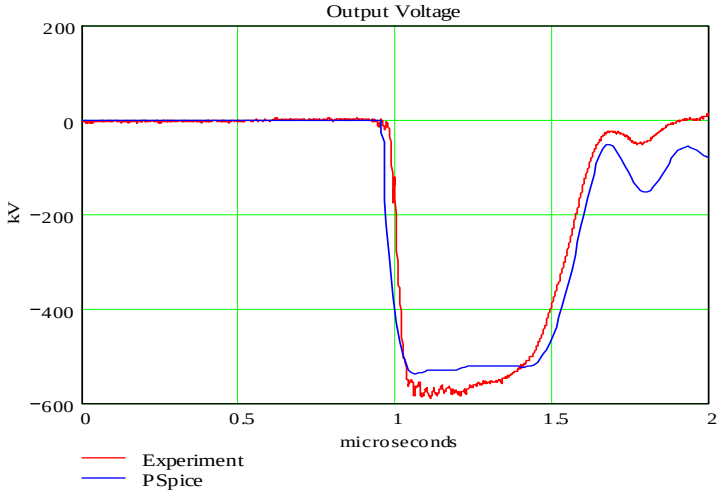


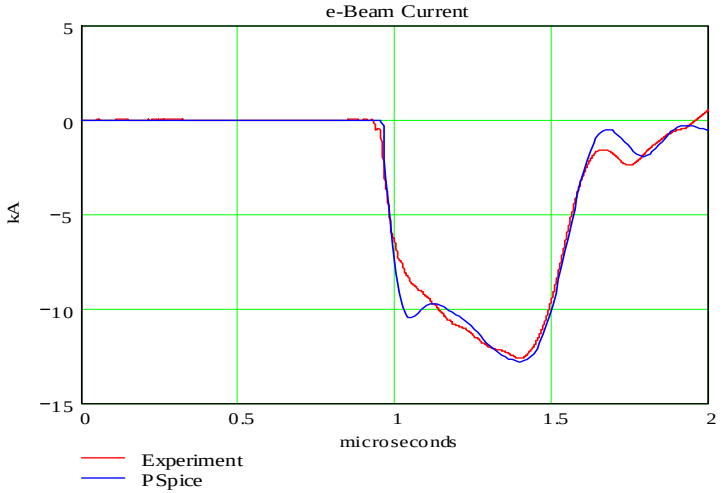
The perveance value (α) is based on previous experiments and simulations, for the 3.7 cm AK gap used in the recent experiments

Pulsed Power Data

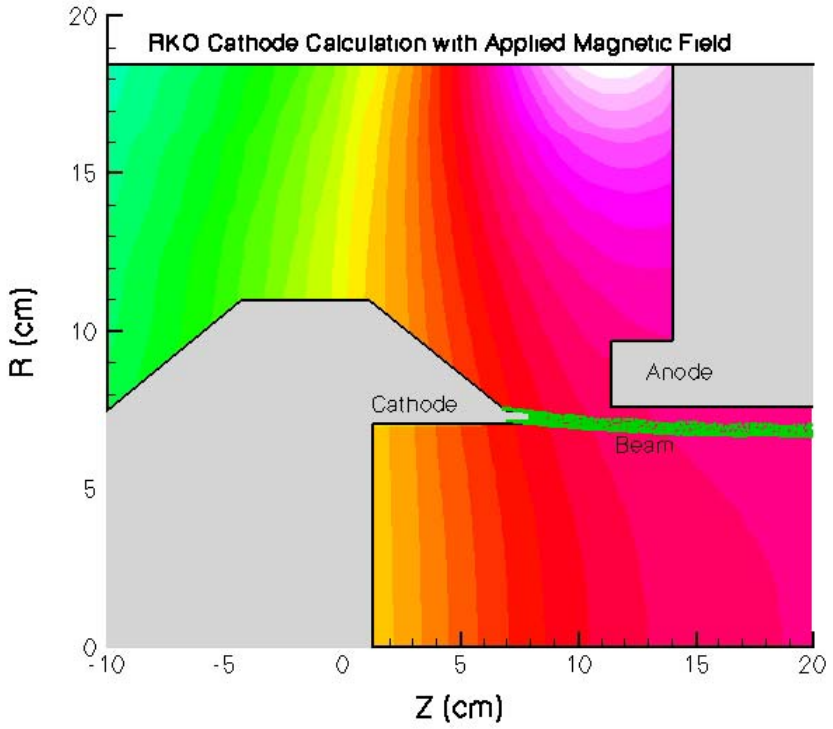


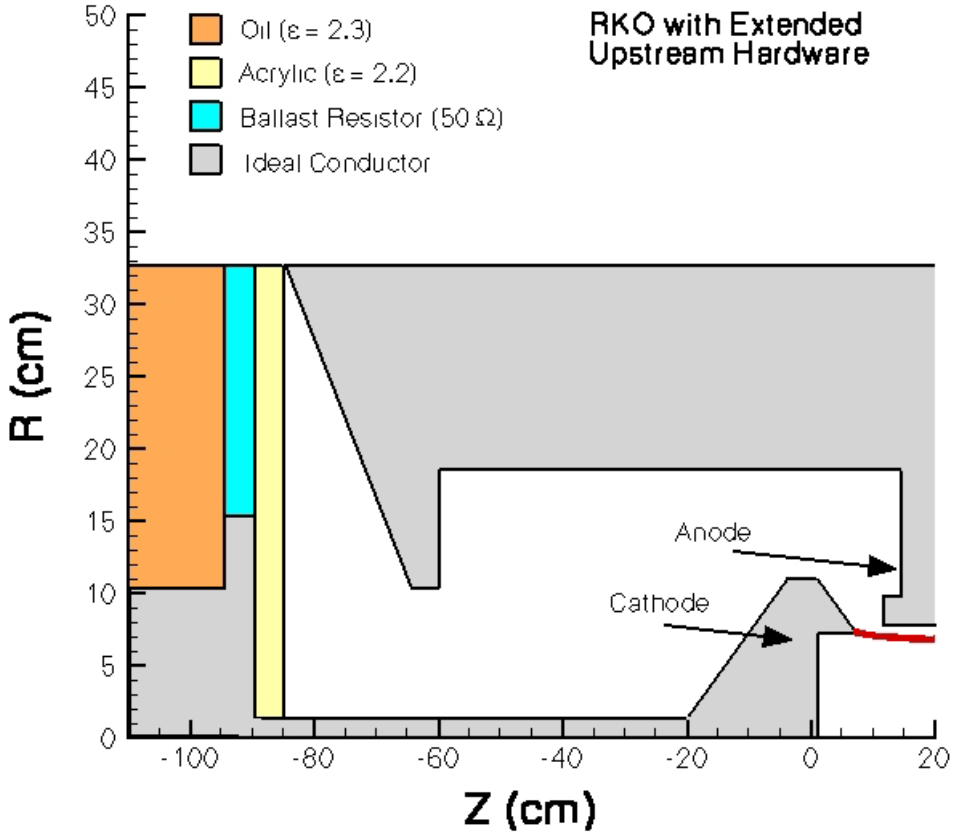




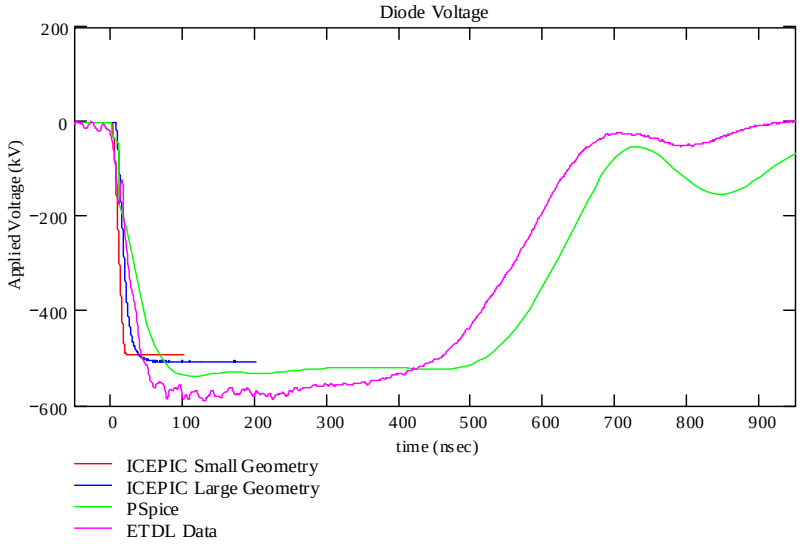


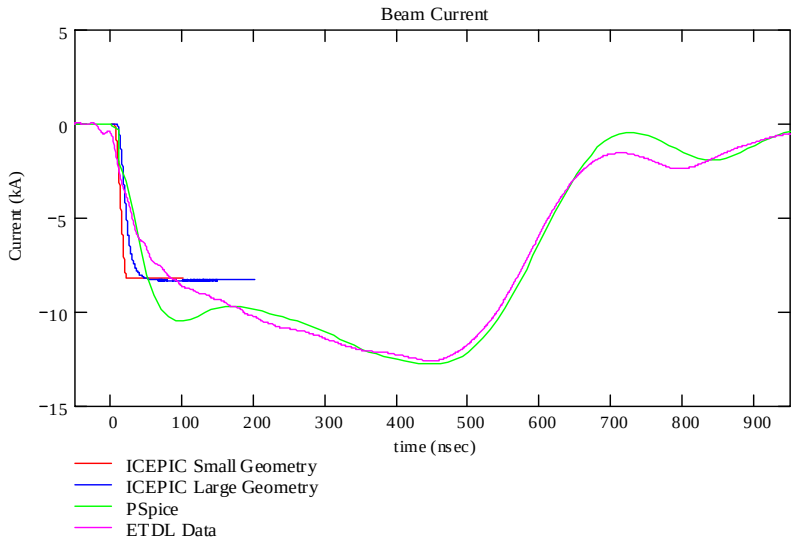
ICEPIC Diode Simulation





Diode Voltage/Current Comparison





Summary

- HFSS and ICEPIC have been used to successfully simulate various aspects of the RKO
- Simulation dimensions must be adjusted from measured experimental values to obtain successful comparison
  - Adjustment is << 10% of the measured value
- The upstream boundary condition is critical to account for the various impedance discontinuities in the experiment.